DESIGN OF A PLANT TO PRODUCE 5 TON PER DAY LIQUID FUEL FROM WASTE PLASTIC (LOW DENSITY POLYETHYLENE)

A THESIS SUBMITTED IN FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF

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In
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By
PENTA VENUMADHAV
111CH0076

Under the Guidance of
Prof. R. K. SINGH

Department of Chemical Engineering
National Institute of Technology
Rourkela
2015

Department of Chemical Engineering

National Institute of Technology, Rourkela

CERTIFICATE

This is to certify that the thesis entitled, **"DESGIN FO A PLANT TO PRODUCE 5 TON PER DAY LIQUID FUEL FROM WASTE PLASTIC (LOW DENISTY POLYETHYLENE)** submitted by Mr. PENTA VENU MADHAV in partial fulfilments for the requirements for the award of Bachelor of Technology Degree in Chemical Engineering at National Institute of Technology, Rourkela is an authentic work carried out by him under my supervision and guidance. To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University / Institute for the award of any Degree or Diploma.

DATE

PROF. R. K. SINGH
Dept. of Chemical Engineering
National Institute of Technology
Rourkela – 769008

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Date: **PENTA VENUMADHAV**

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ABSTRACT

The present work involves the study and design for the production of liquid fuel from waste plastic (LDPE) by thermal pyrolysis. The process is carried out thermal pyrolysis where degradation of larger molecules into smaller molecules. The effect of temperature has been studied at different temperatures 475°c, 500°c, 525°c, 550°c and the following wt. % are 47.3%, 63.2%, 69.8%, 77.07% respectively. The most economical process flow diagram was designed for production of liquid fuel from waste plastic (LDPE). The maximum yield of product is obtained at optimum temperature 550°c.

With the help of product flow rate, the required raw materials are calculated which are 6.48 tons per day to produce 5 ton per day liquid fuel. Residence time is the time required for reaction and this noted as 57 min from the experiment. Design of the reactor is done with help of residence time and flow rate of raw materials and calculated to be 544 liters.

Designing of equipment (vessel) are done with the help of mass balance and heat balances reactions. Volume of the vessel is found out from the steady state heat conduction equations. The optimum diameter and length of the reactor are calculated.

Cost estimation of the plant is calculated and it is found that it is feasible to put a plant of 5tons of liquid fuel and with help of input cost and output cost and then profitability is calculated.

CHAPTER 1

INTRODUCTION

1.1 General background

Plastics are indispensable material used in present world. Plastics are non-biodegradable material which contains carbon, hydrogen and few other elements such as chlorine, nitrogen etc. plastics have properties such as light weight, durability, energy efficiency, coupled with a faster rate of production and design flexibility, these plastics are employed greater importance in industrial and domestic areas. The major problem in worldwide is increasing commodity waste plastics with the increasing in the population. The main origin of the waste plastic is from industrial and domestic wastes due to non-biodegradable nature. Production of plastic is growing increasingly which is more than 200MT worldwide. Due to lack of integrated solid waste management, most of the plastic neither collected nor disposed in a good manner which creates negative impact in the present world.

Plastic waste recycling is done to convert into some useful resources where the plastics are collected and disposed in environment friendly manner. Waste plastic is the one of the prominent source for converting into fuel production because of its high calorific value and high heat of combustion rate. Plastics have different conversion methods which are based on different kinds of plastic.

1.1.1 Low density polyethylene(LDPE)

Low density polyethylene (LDPE) is a thermoplastic made from the petroleum. It was the first grade of polyethylene produced by imperial industries (ICI) using a high pressure process via free radical polymerization. LDPE is commonly recycled and has the number ‘4’ as its recycle symbol. Despite competition from more modern polymers, it contains to be an important plastic grade. LDPE contains the chemical elements carbon and hydrogen. It is defined by a density range of 0.91-0.94 g/cm3.

Its low density resembles the presence of small amount of branching in the chain (on about 2% of the carbon atoms) and this is more open structure. LDPE is most commonly used plastic in daily life like plastic covers, bottles etc.

1.2 Origin of the problem

Two important problems are found for conversion of plastics i.e. scarcity of fossil fuels and solid waste management. Scarcity of resources indicated due to its economic growth is unsustainable without saving fossil fuels like crude oil, natural gas or coal. According to the reports of international energy outlook says that world consumption of fossil fuels such as petroleum and diesel grows from 86.1 million barrels per day in 2007 to 92.1 million barrels per day in 2020, 103.9 million barrels per day in 2030 and 110.6 million barrels per day in 2035 and natural gas consumption increases from 108 trillion cubic feet in 2007 to 156 trillion cubic feet in 2035. The similar way of consumption goes into scarcity of fuels for further hundred years. Conversion of waste plastic to liquid fuel helps in alternate path can contribute to depletion of fossil fuel.

Solid waste management is another important aspect for sustainable development. Plastic is the one of important aspect involved in the solid waste management. Due to the increasing in the use of plastic, which is a non-biodegradable material, due to versatility and relatively low cost. Waste plastic is mostly obtained from the industrial and domestic uses. Advanced research has been done on the waste plastic which can been converted into liquid fuels using different chemical process. Production of liquid fuel is a better alternative as the calorific value of the plastics is comparable to the liquid fuels, around 40MJ/kg and it is carried out by pyrolysis process, occur in the absence of the oxygen at hog temperatures.

1.3 Objective of present work

The overall objective of the project is to study and design of a plant for conversion of waste plastic mainly low density polyethylene into liquid fuel by thermal pyrolysis process. The specific objectives are:

- To study the thermal pyrolysis of waste plastic (low density polyethylene (LDPE)) into liquid fuel.
- To design the plant for conversion of waste plastic (LDPE) to produce 5 tons of liquid fuel per day.

1.4 Organization of thesis

This thesis contains four chapters. The present chapter, chapter-I which is the introduction of plastics and the origin of problems and general introduction. Chapter-2 contains literature review of different kinds of plastics treated for conversion into liquid fuel which useful for recycling of plastics and different methods for recycling of plastics. Chapter-3 contains the material supply of plants, study of plant process, design of plant process using low density polyethylene. Chapter-4 contains summary of the project and results of the process involved.

FIGURE 1.1 Different types of waste plastic (LOW DENSITY POLYETHYLENE).

CHAPTER 2

LITERATURE REVIEW

2.1 Plastics

Plastics are indispensable material present in the world. Plastic is a polymeric group of synthetic or natural materials which contains major composition carbon compounds. Plastics are large group of material which are combinations of oxygen, hydrogen, nitrogen, and other organic or inorganic material which can molded into any form with the help of heating. Plastics are constructed into polymers by single monomers which are repeatedly added by various chemical process. Over last few decades, there is increasingly use of plastic due to its versatile ad affordable. Plastics are easy to use, light weight, and easy to maintain.

Plastics are generalized into two groups like thermoplastics and thermoset plastics. Thermoplastics are linear chain macromolecules in which the atoms and molecules are combined end to end into long series. Formation of linear molecules from vinyl monomers can be achieved by opening the double bond and processes by radial polymerization like polyethylene, polypropylene etc. thermoset plastics are different set plastics are formed step by step polymerization under suitable conditions allowing molecules to condensate the intermolecularity with small by products such as h20,hcletc.at every step.

2.1.1 Low density polyethylene (LDPE)

Low density polyethylene (LDPE) is a thermoplastic made from the petroleum. It was the first grade of polyethylene produced by imperial industries (ICI) using a high pressure process via free radical polymerization. LDPE is commonly recycled and has the number ‘4’ as its recycle symbol. Despite competition from more modern polymers, it contains to be an important plastic grade. LDPE contains the chemical elements carbon and hydrogen. It is defined by a density range of 0.91-0.94 g/cm3.

FIGURE 2.1 Recycle number for LDPE.

Polyethylene produced was only low density plastic produced till 1950. The LDPE was produced by imperial industries in 1933. LDPE was named because it contains different concentrations of branches that hinder the crystallization process, results low density. Ethyl and butyl groups are main branches involved in low density polyethylene. The difference in LDPE and HDPE are degree are branching involved. LDPE is prepared with the monomer ethylene under extreme high pressure of about 350 mega Pascal and higher temperatures of about 350 ‘c in presence of oxide initiators. This process produce both long and short branches polymer. LDPE is flexible material and its melting point is around 110’c.

2.1.1.1 Structure and physical chemistry of LDPE

Ethylene (C2H4) is a gaseous hydrocarbon produced commonly by cracking ethane, which constituent of natural gas or distilled from petroleum. Ethylene molecules consist of two methylene groups linked together by double bond between the carbon atoms. Under the guidance of polymerization catalyst, double bond is broken and an extra bond single molecule is connected leading to formation of polymer of multiple units. The simple structure repeats hundred times of a single molecule which is key to properties of the polyethylene. The long chain like molecules in which hydrogen atoms are connected to a carbon backbone can be produced in linear or branched forms which are known as low density polyethylene. The structure of LDPE are linear, branched and network system. Branched polymer molecules cannot pack together as closely as linear molecules can and hence the intermolecular forces binding these polymers together tend to be much weaker. This is the reason why the highly branched LDPE is very flexible and finds use as packaging film, while the linear HDPE is tough enough to be shaped into such objects as bottles or toys.

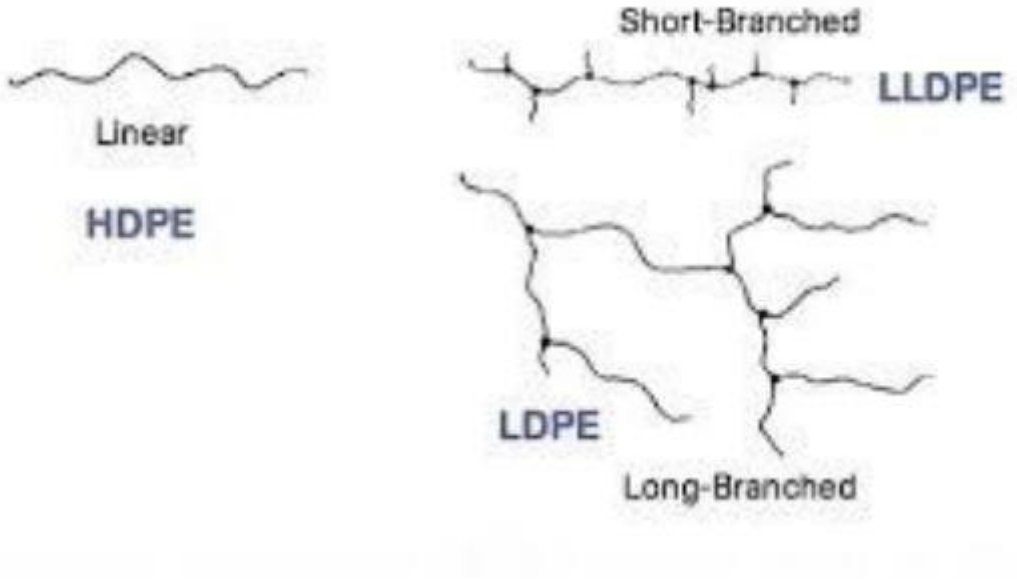

FIGURE 2.2 Structure of LDPE, HDPE and LLDPE.

TABLE 2.1 Physical properties of LDPE

Tensile strength	0.2-.14N/mm2
Notched impact strength	No break
Thermal coefficient of expansion	100-200x10^-6
Max. content use temperature	65’c
Density	0.917-0.93g/cm^3

LDPE is resistant to chemicals like dilute acid, dilute alkalis, oil and greases, aliphatic hydrocarbons, aromatic hydrocarbons, halogenated hydrocarbons and alcohols. LDPE are mi-rigid, translucent, very tough, weatherproof, good chemical resistance, low water absorption, easily processed by most methods, low cost.

2.1.1.2 Uses of LDPE

LDPE is widely used in many application like containers, dispensing bottles, tubing, and plastic bags for computers components, wash bottles and in various packing covers for equipment. LDPE is used in different trays and general purpose containers, corrosion- resistant work surfaces, parts that need to be weld able and machinable, parts that require flexibility, very soft and pliable parts such as snap on lids, six pack rings, juice and milk cartons are made of liquid packing board,

laminate of paperboard and LDPE (as the water proof inner and outer layer), and often with of a layer of aluminum foil (thus becoming aseptic packaging), packaging for computer hardware, such as hard disk drives, screen cards and optical disc drives, playground slides, plastic wraps and etc.

2.1.1.3 Demand for LDPE

The demand for LDPE is highest in Asia and followed by Europe. The increasing demand has been increased with population and Asian demand by volume for LDPE in 2009 was 5.9 million MT. Asia and Europe are the leading users for LDPE around the world but whereas china maintains stable requirements of plastic. The future growth of LDPE provide a depth analysis of the global low density polyethylene (LDPE). Major economic and market trends are affected by the LDPE markets in all regions of world as per the research. The global demand for LDPE is expected to grow at a CAGR of around 2% from 2009 to 2020 according to the GBI research. Over few decades, as per the market LDPE remained applications has begun to stabilize in the very large world scale LDPE equipment. Wiling investors in Iran, the gulf countries, and china have driven a number of new large LDPE projects, which began coming on stream during 2008-10. In the next few years new investments will be made on the North America, Middle East and china.

2.2 Plastic waste recycling

Usage of plastic material has growing in proportion of the both municipal and industrial waste decompose into land. Huge amount of waste plastics and environmental pressures results in recycling of plastics has become an important role in today plastic industry. In today's plastic, waste plastic became a major problem and reuse and recycling process are carried out which are cost effective. The recycling and reuse of plastics make in decreasing of the quality of products which can used in other normal purposes. The recycling are divided into four processes which are

2.2.1 Primary recycling: This type of recycling considered about the materials that are clean and uncontaminated. After the use of the material, the material have been recycled which are comparable with the original plastic or mixed with different kind of plastic for quality. This type of recycling is simple, effective and least cost.

2.2.2 Secondary recycling: This type of recycling is considered as conversion of waste plastics into lower less demanding plastics of lower demand. This type of recycling have two approaches where one approach is to separate the contaminants and been carried out by the primary recycling.

Another approach is to separate from contaminants and re-melt them as a mixture without segregation. This type plastics areu undergone different processes cleaning, drying and compounding.

2.2.3 Tertiary recycling: This type of recycling is considered chemical recycling. The terms chemical recycling and feedstock recycling are collectively considered as advanced technology recycling. In this type, plastics are converted into smaller molecules as chemical intermediates through chemical and heat treatment/ plastics are converted into liquids and solids. Different processes are

2.2.3.1 Chemolysis: This process lead to conversion of plastic back into monomers by depolymerization with the help of different catalyst. Chemolysis processes include range of such as glycolysis, hydrolysis, methanolysis and alcoholysis.

2.2.3.1.1 Hydrolysis: Hydrolysis process lead to reaction of water molecules at the linkage points of the starting materials. Hydrolysis plastics such as polyamides. Polysters, polycarbonates. Polyureas and polyurethanes which are resistant to hydrolysis. Outstanding products are yielded with this process where 100% of the polyether and 90%of amine can be recovered.

2.2.3.1.2 Alcoholysis: B**y** this process, polyurethanes are degraded to give polyhydroxy alcohol and small urethane fragments. Carbon dioxide is not at all formed I this type reaction. In this diol is used for then ureathes are also contains terminal hydroxyl groups. This forms polyurethane foam from polyhydroxy following isocyanides addition and varying in proportions.

2.2.3.1.3 Glycolysis and methanolysis: By this process, degradation takes place in presence of glycol such as ethylene glycol or diethylene glycol and degradation of polymers in the presence of methanol is known as methanloysis.

2.2.3.2 Gasification or partial oxidation: polymeric waste which has good calorific value and this is due to noxious substances like sulfur oxides, dioxins, hydrocarbons and NOx. A waste gasification and smelting system using iron or steel making technologies to produce a dioxin free and purified high calorific gas. In this process, 60-70% hydrogen is recoverd back from partial oxidation.

2.2.3.3. Cracking

2.2.3.3.1 Thermal cracking

Thermal pyrolysis is a process of degradation of polymeric materials heating in absence of oxygen. Usually this process is conducted at around 500-800'c temperatures resulting formation char, liquid formation and resulting non-condensable high calorific gas. This process involves intermediate and intramolecular reactions for the initial degradation into secondary products. These reactions depends on the temperature and residence of products and nature of reaction. Here reactor design plays an important role in thermal pyrolysis.

2.2.3.3.2 Catalytic degradation

Many researches have processed on the thermal cracking for obtaining greater yield of product and reduction of temperature. In this process, degradation takes place with the help catalyst which helps in above reductions. The laboratory experimental set up mostly takes flow reactor. It may distinguish between two mode contacts i.e. liquid phase contact and vapor phase contact. Polymer degrades into lower molecular chains.

2.2.3.3.3 Hydrocracking

This process takes place under high pressure conditions, hydrocarbon molecules are broken into simpler molecules such as gasoline or kerosene by addition of hydrogen molecules in presence of catalyst. This process takes normally in batch autoclave at moderate temperatures and pressure such as 423-673 k and 3-10 Mpa hydrogen. Hydrocracking gives higher yield of products and higher quality from a wide range of feeds. Catalysts used are Pt, Ni, Mo, Fe supported on acid solids.

2.2.4 Quaternary recycling

Quaternary recycling is the process involves recovery of the energy content of plastics. This method undergoes combustion process for the recovery of energy which is most effective method for reduction of volume of organic material. This may then disposed to landfill. Plastics either thermoplastics or thermoset actually yield high energy sources.

2.3 Pyrolysis of LDPE

LDPE pyrolysis have been studied by many researchers for degradation of waste plastic into different products like liquid, gas and solid change depending on various factors such as catalyst, temperature, pressure, nature of reaction, type of reactor used.

2.3.1 Thermal and catalytic pyrolysis

The type on reactor and the effect of temperature on the pyrolysis of LDPE have been studied and results are revised.

The previous thesis by 'Ashish kumar' is done on the conversion of waste LDPE into useful products such as liquid fuel and further separated into diesel and carbon compounds which have high calorific value. The material are mainly industrial and domestic area. Thermal Pyrolysis is the process involves the degradation of the polymeric material by heating on the absence of oxygen. It is the process in which breakage of higher molecular weight compounds into lower molecular compounds. Thermal pyrolysis is the process in which heated up to higher degree temperatures and polymeric materials converted into lower molecular compounds.

Procedure: some amount of waste plastic is heated in reactor and the reactor is placed inside the furnace. The heated material is converted into gases from 450 to 650'c and different yields of gases products are obtained. The gaseous product are then condensed into liquid products and gaseous products. The maximum yield of liquid product is at 550.c. The catalytic pyrolysis involved with different ratios of catalyst to feed involved for increasing the yield of liquid product. Compositions of liquid product are done by FTIR spectroscopy and gas chromatography- mass spectroscopy. The composition of liquid products are alkanes, alkenes and different carbon compounds.

2.4. Mechanics and kinetics of pyrolysis

Degradation of polymers usually taken different on the basis of the carried out reaction: thermal degradation, thermos catalytic degradation, oxidative degradation, heat and oxygen, radiation and photoxidative degradation and chemical degradation. This type of reaction are irreversible reactions and changes of structure are irreversible. As the major waste plastics are polyethylene and polypropylene so experiments carried only on these plastics. The decomposition of plastic results in decreasing of molecular weight and physical changes caused. Chemical reactions and recycling are two different methods caused by the chemicals.

The kinetics and mechanism of these reactions have been studied by different techniques.

2.4.1 Investigative methods for polymer degradation

Three extreme categories of pyrolysis behavior has been carried over and each is different investigation;

1) Cross linking or other reactions in the polymer leading to the formation of Infusible resins, or maybe coke/char precursors.
2) Chain scissions and other processes leading to decrease in the typical molecular weight with the sample.
3) Your formation of major yields of little molecular weight materials, which may be monomeric, oligomeric, or that might originate from substituents on the chain backbone.

2.4.2 Reactions mechanism of polymer degradation

Reactions takes place by cracking of c-c bonds that is done by thermal and catalytic effects of thermos degradation. Thermal and catalytic reactions are not separate from each other therefore in discussing thermos catalytic process which touches both the thermal and catalytic process. Thermal cracking occurs by radial mechanism by initiating radicals are formed by effect of heat. Instability of the macromolecules is due to its presence of weak links of polymer.

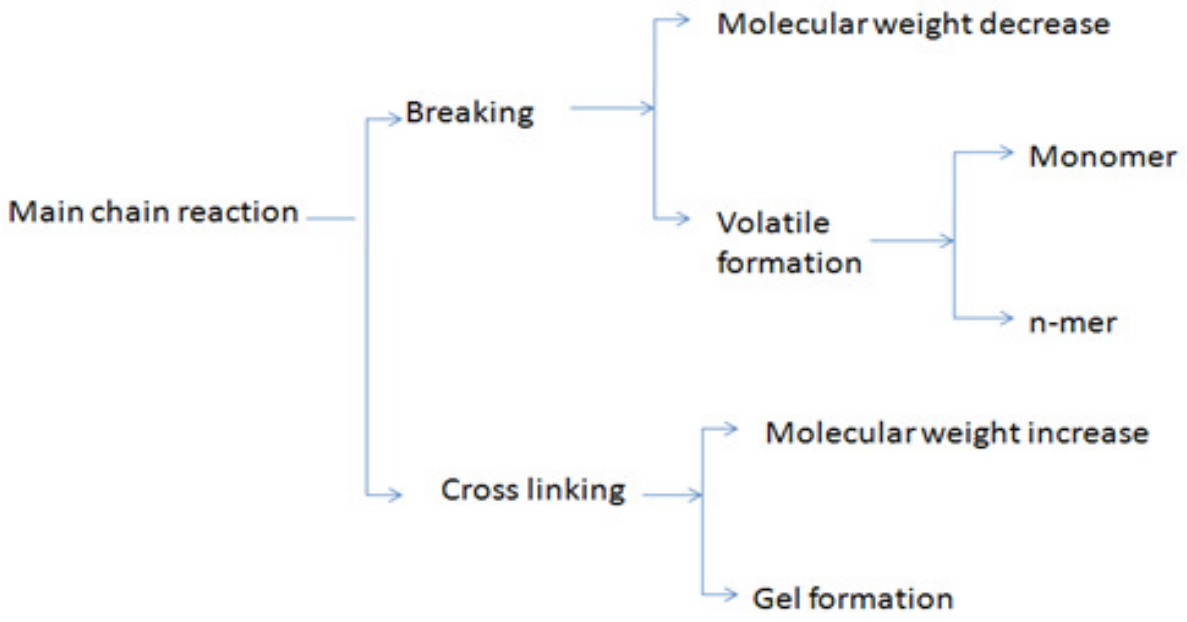

FIGURE 2.3 Reaction mechanism of polymer degradation.

2.4.3 Reaction kinetics of polymer degradation

Decomposition reactions are the degradation which is quite difficult due to its complex in chemical structure. Difference are present in the thermal degradation of waste plastic in absence and presence of catalyst, but type of reactor is also important. Degradation in presence of catalyst is thermo-catalytic degradation. Cracking takes place in batch reactors which results 95% degradation studies (Seo YH et al. 2003, Miskolczi N et al. 2004, Kim JS et al. 2003, Masuda T et al. 1999, Uddin MA et al. 1997, Seddegi ZS et al. 2002, Sakata Y et al. 1997, Grieken RV et al. 2001, Jalil PA 2002, Hwang EY et al. 2002) connected with different techniques for e.g. TG, DTG. TG-MS etc. some kinetic models for thermal degradation were proposed and commonly used approach is first order kinetics for investigating degradation. Different objectives have been proposed for determination of activation energy and kinetic parameters.

2.5 Performance and emission analysis of waste plastics oil in CI engine

Many researchers have been worked and proposed that properties of waste plastic oil had comparable properties with the used fuel in compression ignition engines. Results shown with mixed heavy oils with plastic oils reduces the viscosity significantly and improves performance of the engine.

Mani et al. studied about the plastic oil in DI engine and studied the performance, emission and combustion characteristics of single cylinder, four stroke, air cooled DI diesel engine. With this oil shows stable performance with thermal brake efficiency similar to that diesel. Due to its carbon monoxide emission from waste plastic oil was higher compared to diesel and smoke reduced by 40-50% in waste plastic oil.

Mani et al. Investigated experimentally the influence of injection timing on the performance and combustion characteristics for cylinder, four stroke, direct injection diesel engine using waste plastic oil. Different tests were performed at different injection timing such as 23', 20', 17', 14', and bDTC. Comparing these to the standard injection timing which gives results in decreased oxides of nitrogen, carbon monoxide and unburned hydrocarbon.

2.6 Design of reactor

Reactor design for the mixed flow reactor: Here the procedure is a molar feed A is sent into the mixed flow reactor and waited till reaction occurs and then output product is taken out. The performance equation for the mixed are obtained which makes an accounting makes an accounting of a given component within an element of volume throughout. Taking equation,

Input = output + disappearance by reaction + accumulation

As the accumulation taken as zero and molar feed rate of component are considered. Then considering the reactor design equation are

$$t = \frac{V}{v} = \frac{c_{a0} * X_a}{-r_a} = \frac{c_{a0} - c_a}{-r_a}$$

Where t = residence time.

V= volume of reactor.

v= volume flow rate of a.

c_{a0}= intial concentration of A.

c_a=final concentration of A.

r_a= rate of reaction.

X_a= conversion of A.

CHAPTER 3

FLOW DIARGRAM AND DESCRIPTION OF PROCESS

FLOW DIARGRAM AND DESCRIPTION OF PROCESS

3.1 Feed stock for the plant

Raw Materials are collected are waste plastic (low density polyethylene) collected for municipal waste or the industrial waste. The waste plastics collected are collected mainly LDPE in the form plastic disposal glasses or etc. Skilled Labor are allotted for the collecting only LDPE based on their daily wage. Different kinds of waste plastic (LDPE) are such as plastic bags, laptop covers and normal domestic used plastic which are of lighter density. Most of the raw material is occurred from industries are of less contaminants mixed rather than the domestic use.

3.1.1 Preparation of feedstock

Feed stocks collected are either manually or through automatically cut into small pieces with the equipment. This was done to increase the surface area of contact during melting process. Labor are allotted to do this process according to the daily basis.

3.2 Flow diagram for the plant

3.2.1 Design layout of plant

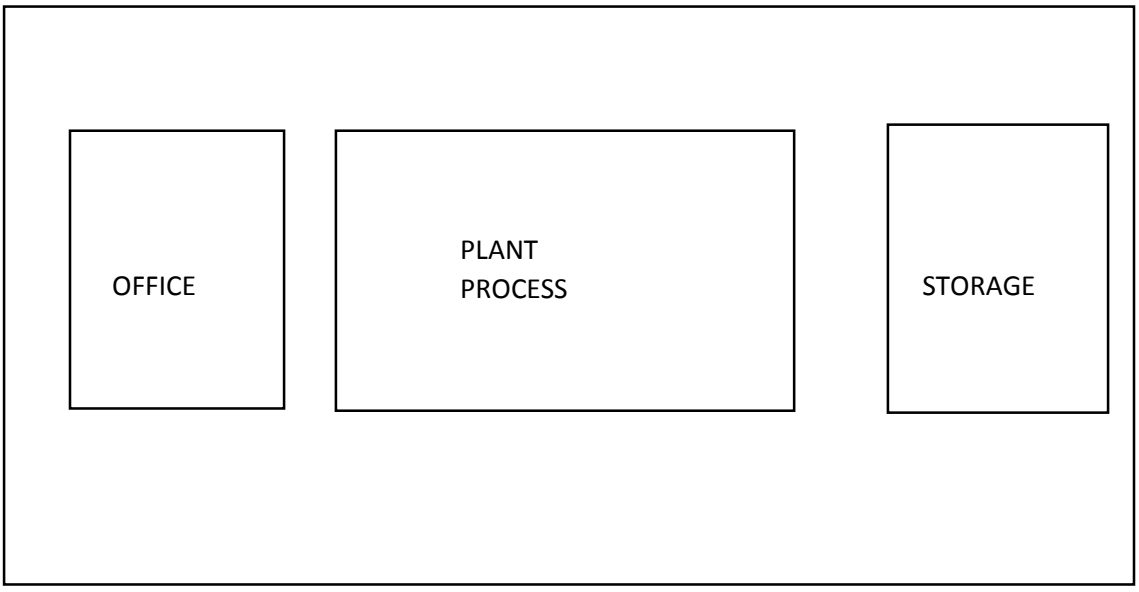

FIGURE 3.1 Simple layout of plant.

3.2.2 Schematic diagram of the plant

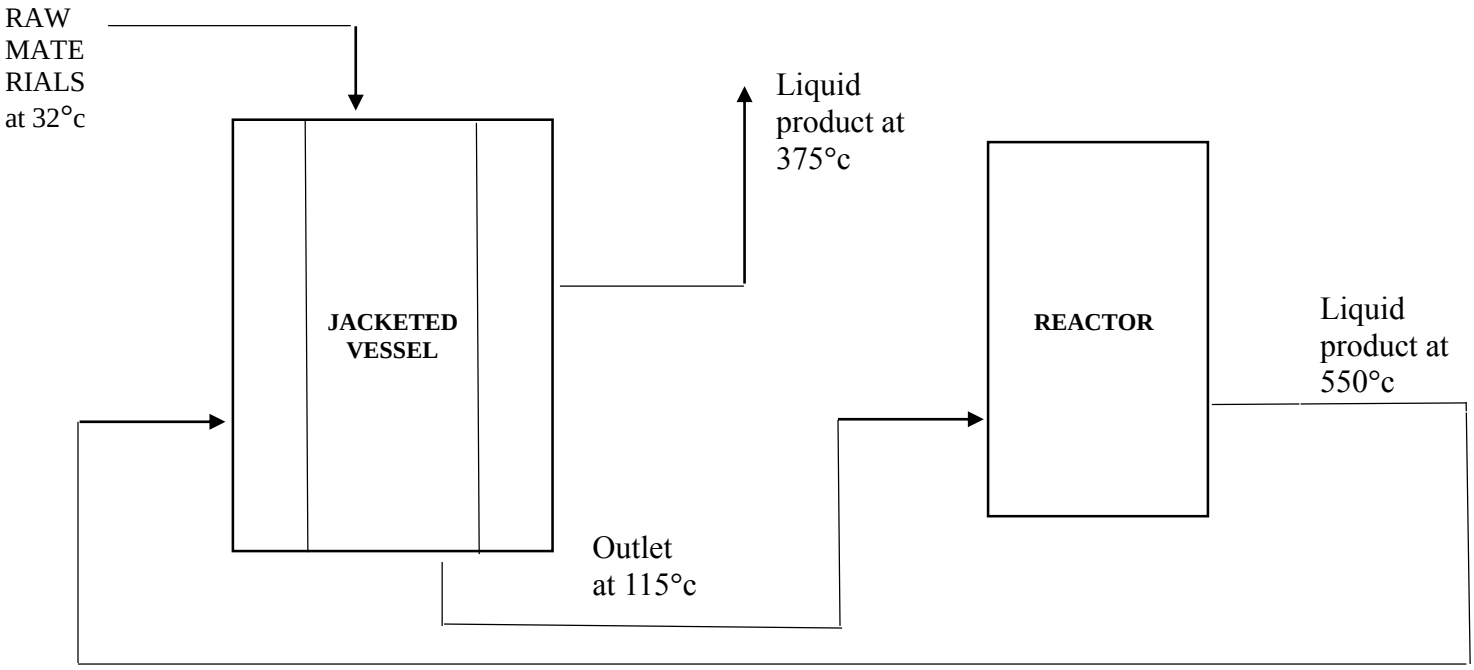

FIGURE 3.2 Process diagram of the plant.

3.3 Description of the procedure

Raw material (LDPE) obtained are first cut into smaller pieces and then entered into the jacketed vessel at room temperature (32°c) and then heated to around 115°c which is melting point of the LDPE. The LDPE are converted into liquid form at 115°c and then passed into the continuous stirred flow reactor and the reaction takes place at optimum temperature 550°c at which the yield is maximum. Product obtained from the reactor is gaseous product which then sent back to the vessel jacket and then gaseous product at 550°c are condensed to liquid and gaseous product . The liquid produced is of 5 tons/day and the gaseous product is sent back and used for heating purpose for the reactor.

Reactants → solid product + liquid product + gaseous product at 550°c.

CHAPTER 4

MATERIAL AND ENERGY BALANCE

4.1 Overall mass and heat balance

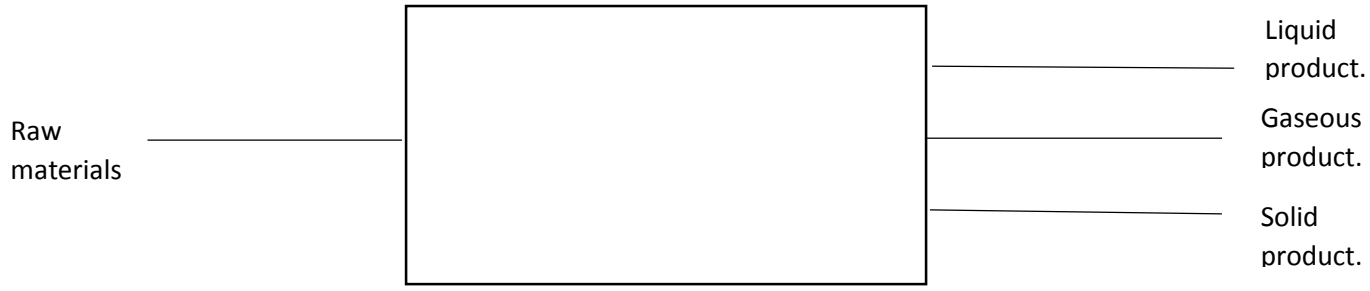

FIGURE 4.1 Block diagram for overall mass balance.

MASS BALANCE:-

Raw materials of the waste plastic (LDPE) → Solid product + Liquid product + Gaseous product.

For finding the raw material of the waste plastic (LDPE) which is calculated from the previous thesis. From the Table 3.1, maximum yield of liquid product produced at 550°c which is an optimum temperature.

Mass balance:-

Input: - Mass of the raw materials = 6.48 tons/day.

Output: - Mass of the solid product = 0.108 tons/day.

Mass of the gaseous product = 1.37 tons/day.

Mass of the liquid product = 5 tons/day.

Total output = 6.478tons/day.

TABLE 4.1 Liquid product produced at different temperatures.

Thermal Pyrolysis of 15 grams of LDPE sample AT following temp(c)	Weight of liquid products obtained (grams)	Weight of solid products obtained (grams)	Weight of gaseous obtained by difference(grams)	Total time for thermal pyrolysis(mins)
475	7.1	0.2	7.7	146
500	9.48	0.15	5.37	80
525	10.48	0.37	4.15	65
550	11.56	0.25	3.19	57
575	11.3	0.09	3.61	41
600	10.12	0.55	4.33	37

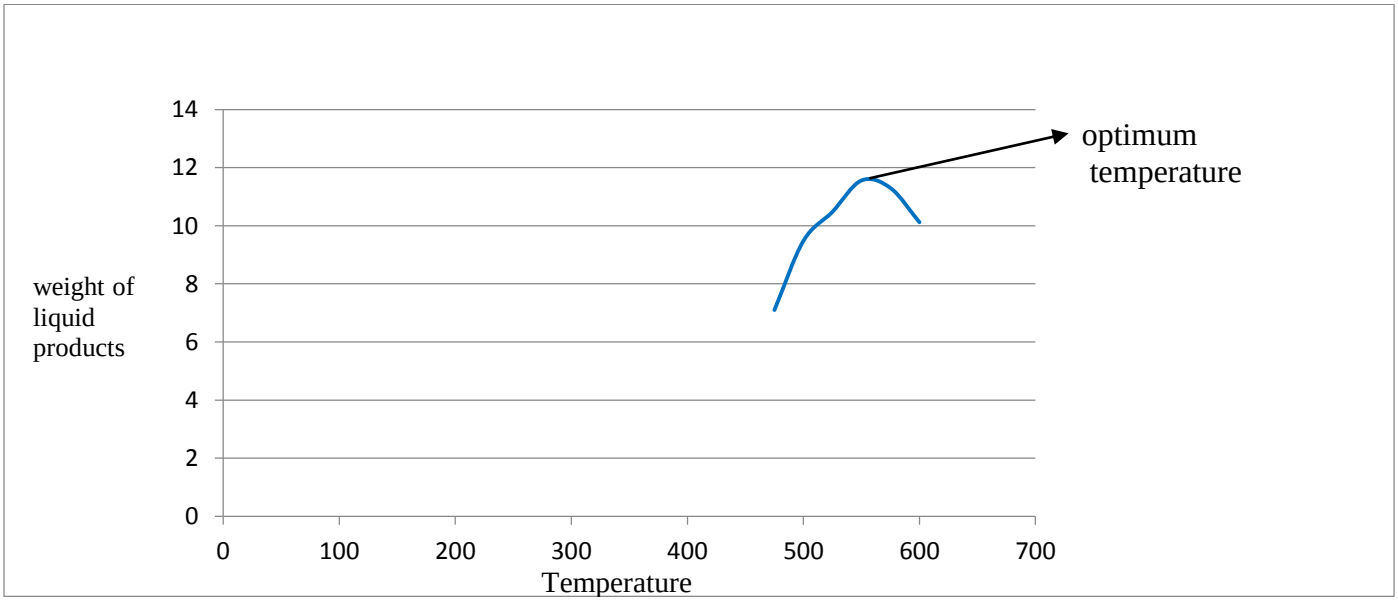

Figure 4.2 Observations of liquid product at different temperatures.

Rate of accumulation is zero because it is a steady state and output is equal to the input and mass is balanced.

TABLE 4.2 properties of LDPE and Liquid product.

Property	**Low density polyethylene(LDPE)**	**Liquid fuel(Product)**
Thermal conductivity(k)($\frac{W}{m*K}$)	0.33	0.15
Viscosity(μ)	3.97*10^{-4}	3.97*10^{-4}
Specific heat(C_p)($\frac{J}{Kg.K}$)	2000	1750
Density (kg/m^3)	940	832

HEAT BALANCE:-

FIGURE 4.3 Block diagram for overall heat balance.

Heat input by raw materials (Q1) = m1*C_{p1}*T1 = 6.48*1000*2000*305/24*3600 = 45750J/s.

Where C_{p1}= Specific heat of raw materials.

T1= temperature of the raw material at input.

m1= mass flow rate of raw materials.

Heat output by liquid product (Q2) = m2*C_{p2}*T1 = 5*1000*1750*648/24*3600 = 65625J/s

Where C_p = specific heat of liquid product.

T2 = temperature of the liquid product.

m2 = mass flow rate of liquid product.

Above block diagram indicates that input heat and output heat balance equation at steady state and output involves three products but due to unknown composition and properties of liquid and gases and hence neglected.

External heat (Q) = Q2-Q1 = 65625-45750 = 19875J/s.

4.2 Mass and Heat balance in Reactor

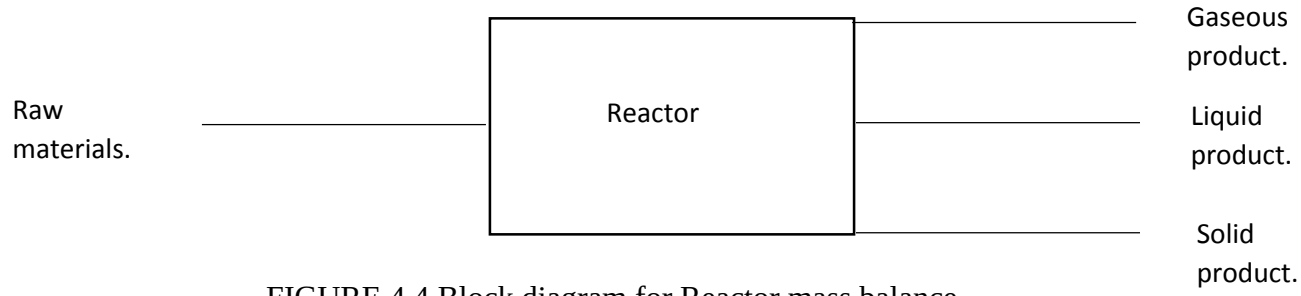

FIGURE 4.4 Block diagram for Reactor mass balance.

Mass balance:-

Input: - Mass of the raw materials = 6.48 tons/day.

Output: - Mass of the solid product = 0.108 tons/day.

Mass of the gaseous product = 1.37 tons/day.

Mass of the liquid product = 5 tons/day.

Total output = 6.478tons/day.

Rate of accumulation is zero because it is a steady state and output is equal to the input and mass is balanced.

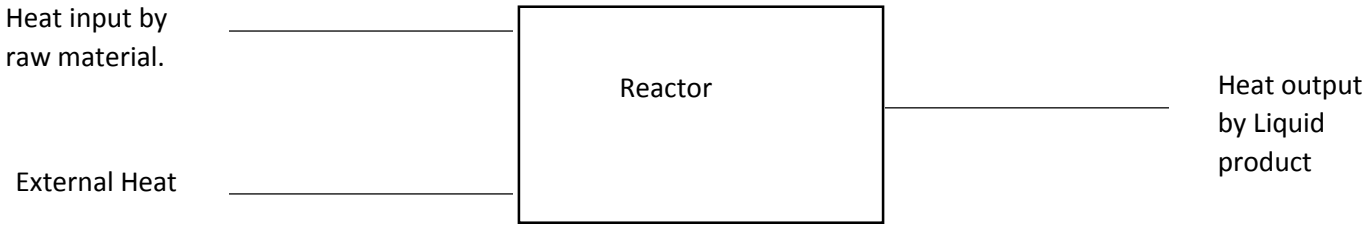

FIGURE 4.5 Block diagram for Reactor heat balance.

Heat balance:-

Input heat:-

Heat required inside the reactor (Q1) = m1*C_{p1}*T1 = 6.48*1000*2220*388/ (24*3600) = 64602W

Heat from the output of the reactor (Q2) = m2*C_{p2}*T2 = 5*1000*1750*823/ (24*3600) = 83347.8W

Heat given from outside (Q) = Q2-Q1 = 18745.8W.

Reactor is processed at steady state and heat is balanced equating the input and output and the heat given from outside of the reactor is 18745.8W.

4.3 Mass and Heat balance in Jacketed Vessel

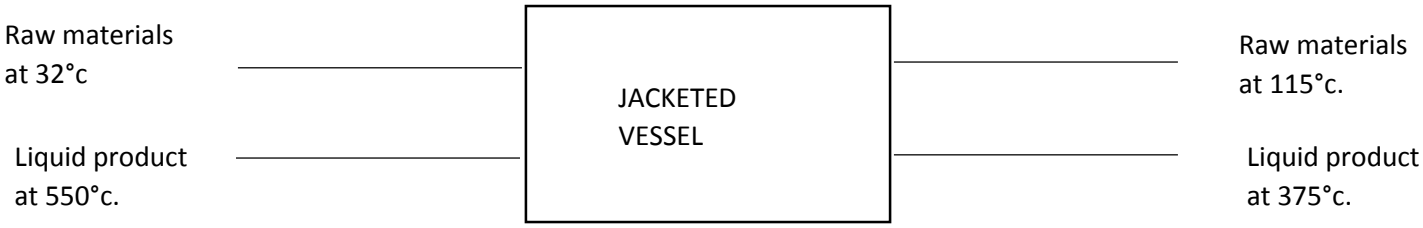

FIGURE 4.6 Block diagram for Vessel mass balance.

Mass balance:-

Input: - Mass of the raw materials = 6.48tons.

Mass of the liquid product = 5tons.

Total input = 6.48 + 5 =11.48tons.

Output: - Mass of the raw materials = 6.48tons.

Mass of the liquid product = 5tons.

Total Output = 6.48 + 5 =11.48tons.

Rate of accumulation is zero because it is a steady state and output is equal to the input and mass is balanced and using heat balances and solved the temperatures below.

HEAT BALANCE:

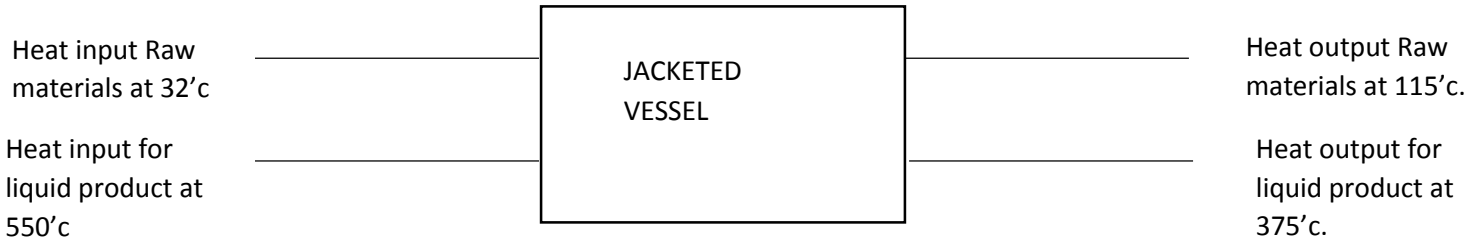

FIGURE 4.7 Block diagram for vessel heat balance.

Using heat balance for the jacketed vessel,

a) Determination of temperature of the product released from vessel.

Temperature is obtained from the vessel using heat balances of the vessel. Input heat contains two forms of heat one by latent heat another by sensible heat due to changing of phase of raw material. In the jacket, only sensible heat is considered because no change in phase.

Heat supplied for input = m1*($c_{p1} * (T_2 - T_1) + \gamma$)

Heat released through output= m2*($c_{p2} * (T_4 - T_3)$)

Required information is

m1= mass flow rate of raw materials. = 6.48 tons per day.

m2= mass flow rate of products. = 5 tons per day.

c_{p1}= specific heat of plastic. = 2300 J/kg.K

c_{p2} = specific heat of liquid fuel = 2220 J/kg K

γ = heat of fusion = 26 kcal/ kg K

T1= heat of raw material at inlet. = 32'c

T2= heat of raw material at output. = 115'c

T3= heat of liquid fuel at inlet. = 550

T4 = heat of liquid fuel at outlet

Considering the heat balance for the vessel and finding out the outlet temperature.

$$\text{m1}*(c_{p1} * (T_2 - T_1) + \gamma) = \text{m2}*(c_{p2} * (T_3 - T_4))$$

6.48* (2300*(115-32) + 26*4.186*1000) = 5 *(2220*(550- T4))

We get the value of T3 is 375.014°c.

CHAPTER 5

DESIGN OF EQUIPMENT

5.1 Design of the reactor

Reactants → solid product + liquid product + gaseous product.

a) For raw material needed:-

From the above research paper, we get 11.56g of liquid product from the 15 g of the raw material.

$$\%yield\ at\ 550^{\circ}C = \frac{11.56}{15} * 100 = 77.07\%$$

For 5 tons per day liquid product, we need

$$raw\ material\ needed = \frac{5}{0.7707} = 6.48 tons/day$$

Raw materials required are 6.48 tons/ day of waste plastic (low density polyethylene).

b) For reactor volume:-

Residence time of the reaction is fount out to be 57 min from the research project. Using the equation

$$t = \frac{V_R}{V_o},$$

Where V_R = volume of the reactor,

V_o = volumetric flow rate of raw materials

For calculating the volumetric flow rate,

Mass flow of the raw materials (m_o) = 6.48 tons /day

= 4.5 kg / min (1ton = 1000 kg and 1day = 1440 min)

Density of the low density polyethylene (d) = 0.94 g/cm3

= 940 kg/m3

Volumetric flow rate = 4.5/940 = 0.00478 m3/s.

Volume of the reactor = 57 * 0.00478 = 0.272 m3.

= 272 liters

The volume of the reactor is found to be 272 liters but due to presence of gases during heating in the reactor. So volume of the reactor is to be considered more than the actual volume needed. The volume reactor is found out to be double the actual volume.

Volume of the reactor = 2* 272 liters = 544 liters = 0.544 m3.

c) Optimum diameter and length of the reactor.

Using optimum conditions, calculating surface area

$$A = pi * D * l + \frac{pi}{2} * D^2,$$

$$F\ (D * L)\ =\ D * L\ +\ D^2/2,$$

$$V = \frac{pi}{4} * D^2 * L,$$

Where D = diameter of the reactor,

L = length of the reactor,

A = surface area,

V = volume of the reactor,

$$F(D) = \frac{4 * V}{pi * D} + \frac{D^2}{2}$$

By differentiating the function of diameter, we get

$$D = (\ 4 * V/pi)^{1/3}$$

$$L = (\ 4 * V/pi)^{1/3}$$

For calculating the diameter reactor, we get

$D = (4 * 0.544/pi)^{1/3}$= $0.884m^3$,

For calculating the length of the reactor, we get

$L = (4 * 0.544/pi)^{1/3}$= $0.884m^3$,

The length and diameter of the reactor obtained to be $0.884m^3$.

5.1.1 Material of construction for the reactor

The reactor is constructed with stainless steel material which has diameter and the length are obtained to be $0.884m$. stainless steel – GRADE 304(UNS S30400). Stainless Steel is used because of its properties high tensile strength, highly resistant towards oxides, acids, bases and organic compounds.

5.2 Design of jacketed vessel

Two process takes places in the vessel primary one is the melting of LDPE into liquid by supplying heat at 115'c from 32'c. Secondary is the cooling process which is obtained from the reactor at 550'c. Initially heating is supplied through the outside for heating of raw material for easy flow into the reactor.

5.2.1 Determination of length, diameter and volume for jacketed vessel

a) Calculation of inner individual heat transfer coefficient.

Heat transfer takes place with phase change into liquid phase and form a film type condensation. The resistance to the flow of heat is that offered by the layer of condensate flowing downward in laminar flow under the action of gravity. For calculating the inner individual heat transfer coefficient,

$$h_i = 1.47 * \left(\frac{k_f^3 * d_f^2 * g}{\mu^2}\right)^{\frac{1}{3}} * Re^{-1/3},$$

Where k_f = thermal conductivity of the fluid,

d_f = density of the fluid,

μ = viscosity of the fluid,

g = gravity due to acceleration = 9.8m/s^2,

Re = Reynolds number = $\left(\frac{4*m}{\pi*D*\mu}\right)$,

h_i = individual heat transfer coefficient,

M =mass flow rate of the raw materials,

D = inner diameter of the jacketed vessel,

Taking diameter as D = 4m, calculating Reynolds number

Re = $\left(\frac{4*6.48*1000}{\pi*4*3.97*10^{-4}*24*60*60}\right)$ = 60.134

$h_i = 1.47 * \left(\frac{(0.33)^3*(940)^2*9.8}{(3.97*10^{-4})\text{^}2}\right)^{\frac{1}{3}} * (60.134)^{-1/3}$ = 4707.15.

b) Calculating the outer individual heat transfer coefficient.

Heat transfer takes places without phase change and fluid contains is the liquid product. Heat transfer takes place by convection without the phase change and flow is laminar flow. For calculating the outer individual heat transfer coefficient,

$$h_o = 1.86 * \left(Re * \mathrm{Pr} * \frac{D_e}{L}\right)^{\frac{1}{3}}$$

Where Re = Reynolds number = $\left(\frac{4*m1}{\pi*D_e*\mu_f}\right)$,

Pr = prandtl number =$\left(\frac{\mu_f*C_p}{k_f}\right)$,

D_e = Equivalent Diameter of the outer jacket =$\left(\frac{2*L*\Delta t}{\Delta t+L}\right)$,

L = length of the outer jacket,

k_f = Thermal conductivity of the fluid,

C_p = specific conductivity of the fluid,

μ_f= viscosity of the fluid,

h_o = outside individual heat transfer coefficient.

Taking Reynold number (1000) and calculating the equivalent diameter,

$D_e = \left(\frac{4*m1}{\pi*Re*\mu_f}\right) = \left(\frac{4*5*1000}{\pi*1000*3.97*10^{-4}*24*60*60}\right)$ = 0.186m,

$\Delta t = \frac{0.186*L}{2*L-0.186}$, ---------- (1)

Calculating the Prandtl number (Pr) = $\left(\frac{3.97*10^{-4}*1750}{0.15}\right)$ = 4.63,

$h_o = 1.86 * \left(1000 * 4.63 * \frac{0.186}{L}\right)^{\frac{1}{3}} = \frac{17.69}{L^{1/3}}$, ---------- (2)

c) Calculating the overall heat transfer coefficient (U_i),

For calculating the overall heat transfer coefficient, overall heat transfer involves heat transfer inside the vessel, heat transfer outside the vessel and the heat transfer through the wall by conduction. Here the heat transfer involved by both conduction and convection and heat transfer through conduction is negligible because of lower thickness and high conductivity and taking $\frac{\Delta x*D_i}{k_m*D_l}$ =0.

$$\frac{1}{U_i} = \frac{1}{h_i} + \frac{D_i}{D_o*h_o} + \frac{\Delta x*D_i}{k_m*D_l},$$

Where D_i = inner diameter of the vessel,

D_o = outer diameter of the vessel =2*$\Delta t + D_i$,

k_m = thermal conductivity of the stainless steel,

D_l = mean diameter of the vessel,

Δx = thickness of the wall,

Δt = thickness of the outer side,

Now for calculating the overall heat transfer coefficient.

$\frac{1}{U_i} = \frac{1}{4707.15} + \frac{4}{(2*\Delta t+4)*\frac{17.69}{L^{1/3}}}$,---------- (3)

$$Q = U_i * A_i * \Delta T_l$$

Where Q = heat transfer through from outside to inside the vessel= 22482.63J/s,

A_i = Area involved inside the vessel = $2* \pi * D_i * L$,

ΔT_l = log mean temperature = $\left(\frac{\Delta T_1 - \Delta T_2}{ln\left(\frac{\Delta T_1}{\Delta T_2}\right)}\right)$= 387.18'K,

ΔT_1= 375-32 = 343'K,

ΔT_2= 550-115 = 435'K,

$U_i * A_i$ = 58.067,

$U_i * L$ = 2.31---------- (4),

From equating 1, 2, 3 and 4 and we found that value of L is 4m and the thickness is found to be $\Delta t = 0.116$ from the equation 1 and the outer diameter is found to be 4.226m.

5.2.2 Material of construction for the jacketed vessel

The reactor is constructed with stainless steel material which has inner diameter and the length are obtained to be 4m and the outer diameter is 4.226m. Stainless steel – GRADE 304(UNS S30400). Stainless Steel is used because of its properties high tensile strength, highly resistant towards oxides, acids, bases and organic compounds.

5.3 Nominal pipe sizes

By calculating the velocity of liquid flown we can calculate sizes of the pipe by Hagen poiseuille equation, i.e.

$$\Delta p = \frac{128 * \mu * L * Q}{\pi * D^4},$$

Where μ = viscosity of the liquid,

Δp = pressure difference between the pipe,

L= length of the pipe,

Q volumetric flow rate,

From the table of the nominal pipe size, the value of pipe size is found out to be ¾" (inches).

CHAPTER 6

COST ESTIMATION

6.1 Cost estimation of the plant

Cost estimation is calculated from considering only input raw material and the output raw material. The input raw material obtained can be calculated either by giving daily labor wage or from purchasing from the recycling industries. Output cost involves are only the price of the liquid fuel and there is deduction of initial heat supplied to the equipment for heating.

COST OF INPUT MATERIALS:-

Cost of the raw materials = Rs.15/Kg.

Total amount of raw materials = 6.48 tons/day = 6480Kg/day.

Total cost of the raw materials = 6480*15 = Rs.97200/day.

Assuming working days =340 days.

Total cost of the raw materials per annum = 97200*340 = Rs.33048000 = $ 517750.27 (1$= Rs.63.83).

COST OF OUTPUT MATERIALS:-

Cost of the liquid product = Rs.35/Kg.

Total amount of liquid product = 5tons/day = 5000Kg/day.

Total cost of the liquid product = 5000*35 = Rs.175000/day.

Total cost of the liquid product per annum = 175000*340 = Rs.59500000 = $932.163.55.

COST OF WORKERS:-

Workers involved are 4 unskilled and 2 skilled workers and the cost of the workers are involved.

Cost of the workers per day = 4*200 + 2*240 = Rs.1280/day.

Cost of the workers per annum = 1280*365 = Rs.467200 per annum. = $7319.44 per annum.

ESTIMATION OF THE CAPTIAL INVESTMNET:-For estimation of the cost of the capital investment, the method of percentage pf delivered equipment cost is involved. For calculating the

cost of the equipment and first we have to calculate the surface area and cost of both the jacketed vessel and the reactor.

Surface area of the reactor = π*(D^2+D*L) = $\pi * ((0.884)^2 + 0.884 * 0.884)$= 4.91$m^2$.

Surface area of the jacketed vessel = π*Di*L+ π*Di^2+2*(L*Δt) = 3.14*4*4+3.14*16+2*(0.113*4) = 101.43m^2.

Cost of stainless steel for 5mm of thickness = \$38.297/m^2.

Total cost of material of the equipment = 38.297*(101.43+4.91) = \$4027.5.

Total cost of equipment including the making cost = 1.3 *4027.5 = \$5235.75. (Assuming the making cost is 30%).

Total fixed cost is obtained from both the direct cost and the indirect cost. Now calculating the fixed capital investment by the percentage equipment cost we get,

TABLE 6.1 Determination of fixed capital investment.

COMPONENTS	COST(\$)
Purchased equipment(delivered),E	\$5235.75
Purchased equipment installation,39% E	2041.94
Instrumentation(installed),28% E	1466.01
Piping(installed),31% E	1623.08
Electrical (installed),10% E	523.57
Building (including services), 22% E	1151.86
Yard improvements, 10%E	523.57
Service facilities (installed), 55% E	2879.66
Land, 6% E	314.45
Total direct plant cost D	\$ 15759.89
Engineering and supervision, 32% E	1657.44
Construction expenses, 34% E	1780.15
Total direct and indirect cost (D+I)	\$ 19197.48
Contractor's fee, 5%(D+I)	959.874

Contingency, 10% (D+I)	1919.748
Fixed capital investment	$ 22077.102

For installation of the plant, we should take loan in the banks at the interest of 14 % and the method is simple interest.

Total amount = $22077.102 + = $ 517750.27 = $539827.372.

For calculating the Simple Interest,

$$SI = \frac{P*R*T}{100}$$

Where P = principal amount,

R= rate of interest = 14%,

T = time period = 10 years.

Simple interest per ten years, SI = $\frac{539827.372*14*10}{100}$ = $755758.32.

Total amount paid for the year = $53982.7372 + $75575.832 = $129558.562

Insurance for every year is (Assuming 1% per year) = $220.77.

For calculating the depreciation using straight line method,

Total time = 10 years. Salvage value = 0

Depreciation cost of the equipment = (equipment cost – salvage value)/total time =5235.75-0/10=$523.575.

Net profit involves both the direct cost, indirect cost and the other costs.

Net profit = cost of output materials – cost of input materials – insurance cost – depreciation cost-labor cost – interest per year,

Net profit = $932163.55-$517750.27-$7319.44 -$129558.562-$523.575-$220.77 = $276790.933.

Gross profit is calculated by after paying the income taxes and the income tax percentage is 34%. Gross profit per year = (1-0.34)*276790.933 = $182662.21= Rs.1,16,59,329.23 per year.

CHAPTER 7

INSTRUMENTATION AND CONTROL DIAGRAM

INSTRUMENTATION AND CONTROL DIAGRAM

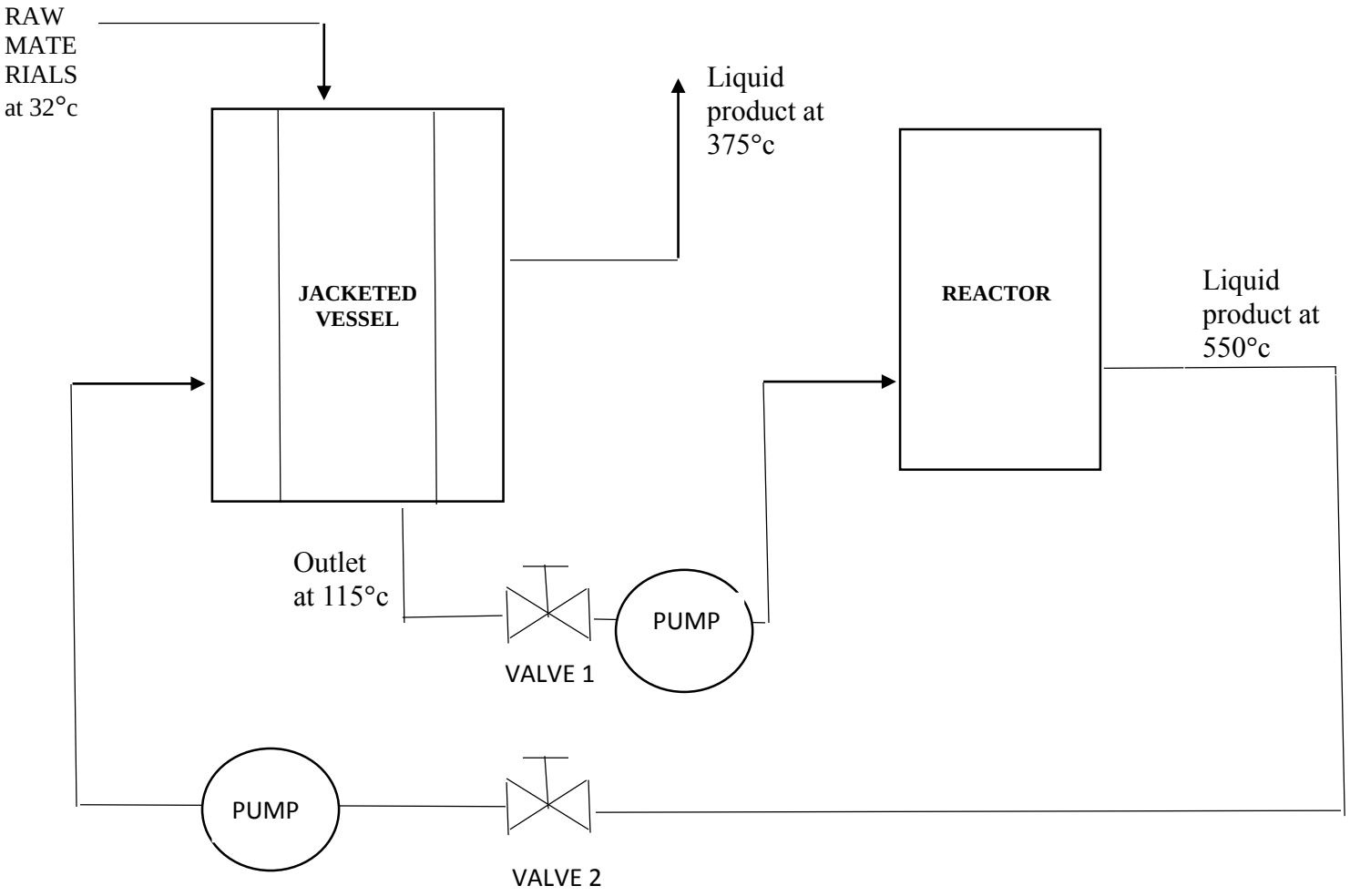

FIGURE 7.1 Plant diagram with instrumentation.

7.1 Valves

Two valves of gate valves are used because of low pressure difference. Valves are used for control the flow of the liquid and the gases product obtained. Gate are generally used during straight line flow of fluids and minimum restriction. Gate are mostly used in petroleum industries because of their ability to cut through liquids.

SPECIFICATIONS:-

Type: Gate Valve

Pipe Size (Inch): ¾

End Connections: FNPT x FNPT

Material: Brass Disc Style Solid Wedge

WOG rating (psi): 200

WSP Rating (psi) 1

Bonnet Style: Bolted Class 200

Special Item Information: Lead-Free.

7.2 Pumps and Rotameters

Pumps used are centrifugal pumps which are used to lift upto certain height of 10m. Two pumps are used one is pumping liquid raw material of lower temperatures and another is used for pumping product at higher temperatures.

Pump1 Specifications:

Flow Rate (min): 1 L/min (0.26 gpm)

Flow Rate (max): 27 L/min (7.1 gpm)

Head (max): 14 Meters H2O (26 ft.)

System Pressure (max): 13.8 bar (200psi)

Viscosity Range: 0.2 to 100 cP

Weight: 0.75 lbs

Standard Ports: 3/8"-18 NPT (F) Inlet; 1/4"-18 NPT (F) Outlet

Recommended Max Speed: 10,000 RPM

Pump2 Specifications:

Ship Weight 14.0 lbs

Flow (GPH) 720

Volts 110

Amps 2.75

HP 1/2

Max. Total Head (ft.) 110

Max. Suction Lift (ft.) 20

Max. PSI 55

Suction Port (in.) 1

Discharge Port (in.) 1

Self-Priming No

Pump HousingCast iron

Impeller Shaft Cast brass

Dimensions L x W x H (in.) 10 1/4 x 5 5/8 x 6 1/8

Rotameters used are should be in the range from 1- 10 l/min and two Rota meters are used to measure the flow rate of the liquids. Two rotameters are used one is pumping liquid raw material and anther is for pumping product.

CHAPTER 8

RESULTS AND DISCUSSION

RESULTS AND CONCLUSION

Pyrolysis of LDPE takes long enough to react and observed the yield of product at different temperatures and found maximum yield of the product is obtained at 550°C which is 77.07%. From the yield of the liquid product determined the amount of raw materials i.e.6.48 tons/day, amount of liquid product i.e.5 tons/day, amount of solid product i.e.0.108tons/day and amount of liquid product i.e. 1.37tons/day. Simple layout of plant and process plant design of the plant and plant consists of different sections office, process layout and storage and process layout consists of office, process layout and storage.

Reactor design is done using the reactor design equations and found volume to be 277 liters due to the presence of gaseous volume is doubled i.e.544litres. The dimensions of the reactor if found to be 0.884m in both length and diameter using optimum conditions.

Design of jacketed vessel are designed with heat transfer inside the vessel is taken with phase change and heat transfer outside the vessel without phase change. Calculating the individual heat transfer coefficient of both outside and inside the vessel and heat transfer through the conduction and solved by different iterations and found the inner diameter i.e.4m and outer diameter i.e.4.226 and length found to be 4m.

Cost estimation is done using the method of percentage of equipment delivered by initially calculating the surface area and taking thickness of 5mm and found total cost of equipment $5235.75 and found the fixed capital investment to be $22077.102. Net profit is calculated by taking all the loan cost, deprecation cost, labor cost and input materials and insurance i.e. $276790.933 per year and gross profit found after paying taxes which is 34% i.e. Rs.1,16,59,329.23 per year($182662.21).

CHAPTER 9

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